Claim 1 stands rejected under 35 U.S.C. § 102(b) as allegedly being anticipated by U.S. Patent No. 5,481,152 to Buschulte (Buschulte). In this paper, claim 1 is amended to include all of the features of claim 6 (resulting in the cancellation of claim 6). Thus, the rejection of claim 1 is moot, and withdrawal of the rejection is requested.

Claim 7 stands rejected under 35 U.S.C. § 103(a) as allegedly being obvious from Buschulte. Because claim 7 depends from allowable claim 1 (as amended), claim 7 is now properly allowable.

III. New claims

New claims 75-107 are added by this amendment. No new matter has been added by this amendment. Support for each new claim is summarized in the chart below.

New independent claim 75 recites all of the features of original claims 1 and 2.

New independent claim 82 recites all of the features of original claims 1 and 4.

New independent claim 88 recites a micro-transducer that comprises a working fluid contained within a cavity, a piezoelectric unit operable both as an actuator to compress the working fluid and as a generator to generate an electric charge whenever the working fluid expands. A heat source and a heat sink are positioned such that thermal energy flows from the heat source to the heat sink through the working fluid. Buschulte neither teaches nor suggests such a combination of features. Buschulte also does not teach or suggest any of the respective combinations of features recited in claims 89-93 that depend from claim 88.

New independent claim 94 recites an apparatus that comprises a first major layer and a second major layer. The first and second layers form a plurality of piezoelectric micro-transducers. Each micro-transducer comprises a respective fluid cavity formed between the

first and second layers, a working fluid disposed in the cavity, and a respective piezoelectric unit. Buschulte neither teaches nor suggests such a combination of features. Buschulte also does not teach or suggest any of the respective combinations of features recited in claims 95-99 that depend from claim 94.

New independent claim 100 recites an energy-conversion apparatus that comprises a first pair of first and second substrates forming a respective plurality of micro-transducers, and a second pair of first and second substrates forming a respective plurality of micro-transducers. The first pair of substrates is stacked superposedly with respect to the second pair of substrates. Buschulte neither teaches nor suggests such a combination of features. Buschulte also does not teach or suggest any of the respective combinations of features recited in claims 101-103 that depend from claim 100.

New independent claim 104 recites a micro-transducer that comprises a compressible and expansible working fluid contained within a fluid-tight cavity and a piezoelectric unit adjacent the cavity. The piezoelectric unit is operable as an actuator to compress the working fluid whenever an electric field is applied to the piezoelectric unit. The piezoelectric unit also is operable as a generator to generate an electric charge whenever the working fluid expands. Buschulte neither teaches nor suggests such a combination of features. Buschulte also does not teach or suggest any of the respective combinations of features recited in claims 105-107 that depend from claim 104.

In view of the foregoing, claims 1-5, 7-21, and 75-107 are properly allowable.

New Claim	Support for New Claim
75	original claims 1 and 2
76	original claim 3
77	original claim 6
78	original claim 7
79	page 8, lines 15-17 of the specification
80	page 7, line 30 and FIG. 1 of specification
81	original claim 15
82	original claims 1 and 4
83	original claim 5
84	original claim 6
85	original claim 7
86	page 8, lines 15-17 of the specification
87	original claim 15
88	page 9, lines 12-31 and FIGS. 2A-2D of the specification
89	original claim 2
90	original claim 4
91	original claim 6
92	page 8, lines 15-17 of the specification
93	page 14, lines 9-10 of the specification
94	page 12, line 24 through page 13, line 3 and FIG. 5 of the specification
95	page 12, line 24 through page 13, line 3 and FIG. 5 of the specification
96	page 12, line 24 through page 13, line 3 and FIG. 5 of the specification
97	page 12, line 24 through page 13, line 3 and FIG. 5 of the specification
98	page 12, line 24 through page 13, line 3 and FIG. 5 of the specification
99	page 12, line 24 through page 13, line 3 and FIG. 5 of the specification
100	page 12, line 24 through page 13, line 3 and FIG. 5 of the specification
101	page 12, line 24 through page 13, line 3 and FIG. 5 of the specification
102	page 12, line 24 through page 13, line 3 and FIG. 5 of the specification
103	page 12, line 24 through page 13, line 3 and FIG. 5 of the specification
104	page 9, lines 12-20 of the specification
105	page 7, line 30 and FIG. 1 of the specification
106	original claim 1
107	original claim 15

IV. Conclusion

The present application is in condition for allowance and such action is respectfully requested. If any further issues remain concerning this application, the Examiner is requested to call the undersigned to discuss such matters.

Respectfully submitted,

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Marked-up Version of Amended Claims and Specification Pursuant to 37 C.F.R. §§ 1.121(b)-(c)

In the Claims:

Please amend claim 1 as follows:

1. (Amended) A micro-transducer comprising:

a first membrane;

a second membrane comprising a first electrode, a second electrode, and a piezoelectric member disposed therebetween;

a fluid-tight cavity cooperatively formed between the first and second membranes; and

a working fluid disposed in the cavity, <u>wherein the working fluid is a saturated mixture of vapor and liquid</u>.

In the Specification:

Please replace the paragraph on page 7, lines 12-20 with the following:

FIG. 1 shows an enlarged cross section of a micro-transducer 10 according to [a] one embodiment. The micro-transducer 10 in the illustrated configuration has a cell-like structure that comprises a first major layer 12 and a second major layer 14. The micro-transducer 10 has a generally rectangular shape, although in other embodiments the micro-transducer 10 may be circular or any of other various shapes. In a working embodiment, the first and second major layers 12 and 14 comprise silicon wafers. However, the micro-transducer 10 may be fabricated from materials other than silicon, such as quartz, sapphire, plastic, ceramic, or a thin-film metal such as aluminum. Methods for manufacturing the micro-transducer 10 from a silicon wafer or other equivalent material are described in detail below.

Please replace the paragraph on page 12, lines 17-23 with the following:

Although a single heat engine 42 may be sufficient to supply the power requirements for certain applications, multiple heat engines may be connected in parallel to increase power output. For example, if one heat engine operating at a predetermined cycling frequency generates one milliwatt, then ten heat engines connected in parallel and operating at the same frequency would generate ten milliwatts. It is then possible to provide a power source that is operable to generate anywhere from one milliwatt to several watts of power, or [move] more, by varying the number of heat engines.

Please replace the paragraph on page 12, line 24 through page 13, line 3 with the following:

Referring to FIG. 5, for example, there is shown an apparatus 70 comprising pairs 72 of first and second substrates 74, 76, respectively, (e.g., pairs of silicon wafers) stacked superposedly with respect to each other so as to form a system of cascading levels, each of which [operating] operates over its own temperature differential. An array of identical heat engines 42 are micro-machined into each pair 72 of first and second substrates 74 and 76, respectively, and an intermediate layer 80 (e.g., a layer of photo-resist material) is disposed between each pair of substrates. In this arrangement, each heat engine 42 is aligned with another heat engine 42 of an adjacent level, with an intervening insulating layer of air. Each heat engine 42 comprises a flexible first membrane 18 having a piezoelectric unit (i.e., a piezoelectric layer disposed between two electrodes) and a substantially rigid second membrane 16. Thermal switches or contacts 78 may be positioned on the second membranes 16 of the heat engines 42.

Please replace the paragraph on page 14, lines 16-28, with the following:

In one example of a micro-heat engine 42, the first membrane 18 has a thickness of about 2 microns, the second membrane 16 has a thickness of about 5 microns, and the thickness of the engine cavity is about 25 microns. The total length of the conduction path through the heat engine is therefore about 32 microns. The surfaces of the second and first membranes have dimensions of approximately 2.0 millimeters by 2.0 millimeters, which provides an aspect ratio of about .0160 and a heat-transfer area of approximately 4.0 millimeters [2] at each membrane. It has been found that the foregoing dimensions will ensure a maximum surface area per unit volume of working fluid and a conduction path sufficiently short to drive heat through the heat engine. The thicknesses of the silicon layer 24 and the silicon oxide layer 26 of the first membrane 18 are about 600-nm and 400-nm, respectively. The top electrode 18 comprises a 20-nm thick layer of Ti and a 200-nm thick layer of Pt. The piezoelectric member 34 comprises a 500-nm thick layer of PZT. The bottom electrode comprises a 200-nm thick layer of Au. The working fluid is R11.

Please replace the paragraph on page 17, lines 12-21, with the following:

As with the heat engine 42 of the present invention, the heat pump 60 integrates all heat-pump functions into a self-contained cell-like structure. Also, similar to the system of cascading heat engines 42 of FIG. 5, multiple heat pumps 60 may be arranged in a similarly [by] configured system of cascading levels in order to increase the rate of cooling and the temperature differential over the rate and differential obtainable using only a single heat pump. As an example, if a single heat pump 60 cools a cold space by 10°C, then ten similar

heat pumps 60 stacked in a cascade array may cool the lowermost cold space of the cascade by 100°C. In addition, if a single heat pump 60 transfers 0.1 Watt of thermal power out of a cold space, then ten heat pumps 60 deployed in parallel may transfer 1.0 Watt of thermal power out of the same cold space.

Please replace the paragraph on page 18, lines 11-20 with the following:

To form the piezoelectric layer 34 for each micro-transducer 10, a solution deposition route for PZT deposition is carried out on the first wafer 88. First, a solution containing the stoichiometric ratio of Pb, Zr, and Ti required for forming the Perovskite phase is spin-coated onto the layer of platinum. The first wafer 88 is then heated in air to 100°C for 5 minutes and to 350°C for 5 minutes. The spin-coating and heating process is then [be] repeated until the PZT layer is about 500-nm, after which the first wafer 88 is heated in a furnace to 700°C for 15 minutes. The steps of spin-coating and heating the wafer 88 in air to 100°C for 5 minutes and to 350°C for 5 minutes is repeated until the final thickness of the piezoelectric layer 34 is achieved, which desirably is about 500-nm. Once the final thickness of the piezoelectric layer 34 is achieved, the first wafer 88 is again heated in a furnace to 700°C for 15 minutes.

Please replace the paragraph on page 27, lines 7-18, with the following:

<u>Micro-Rankine Cycle Heat Engine</u>

According to another aspect of the invention, one or more piezoelectric micro-transducers are employed to extract work from a working fluid to provide useable electrical energy in a manner that is similar to a conventional large-scale Rankine cycle heat engine. FIG. [18] <u>17</u> is a schematic illustration of a micro-Rankine cycle heat engine, indicated

generally at 600, according to one embodiment. Conventional large-scale engines based on the Rankine cycle employ a working fluid for producing mechanical work and a fuel for heating the working fluid. For example, in a conventional steam engine, a fossil fuel, such as coal, is burned to heat the working fluid, i.e., steam. In the present embodiment, however, a single fluid can serve as both the working fluid and the fuel of the heat engine 600. The working fluid/fuel desirably comprises a fluid that is volatile, lightweight and has a low vapor pressure. Examples of such fluids include, without limitation, butane, propane, ethanol, methanol, and the like.

Please replace the paragraph on page 27, line 19-24 with the following:

The heat engine 600 includes a reservoir 602 for storing working fluid/fuel, a boiler 604, a first superheater 606, a first expander array 608, a second superheater 610, a second expander array 612, a third superheater 614, a third expander array 616, a fourth superheater 618, a fourth expander array 620, and at least one combustor 622. Each of the expander arrays 608, 612, 616, 620 in the present embodiment comprises one or more piezoelectric micro-transducers having free-vibrating cantilevers, such as the apparatus 300 of FIG. 14.

Please replace the paragraph on page 27, lines 25-28 with the following:

At the beginning of the cycle, working fluid/fuel flows from the reservoir 602 into the boiler 604, in which the working fluid/fuel is heated [until] to a saturated vapor. The saturated vapor flows from the boiler 602 into the first superheater 606, in which the vapor is further heated to a superheated condition.